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1962 SPRUCE BUDWORM CONTROL PROJECT IN WASHINGTON

by

P. W. Orr

Division of Timber Management
Insect and Disease Control Branch
U. S. Forest Service
Pacific Northwest Region
Portland, Oregon

CONTENTS

SUMMARY

From June 25, 1962 to July 11, 1962 aerial spraying operations against the spruce budworm in Yakima and Klickitat Counties, Washington resulted in 99.1 percent larval mortality. Mortality ranged from 97.4 percent to 100 percent, the highest yet attained on any budworm control project in this Region.

The area was sprayed with DDT. One pound of technical grade insecticide was dissolved in 1.25 quarts of an auxiliary hydrocarbon solvent and then diluted with enough number 2 fuel oil to make one U. S. gallon. This was applied at the rate of one gallon per acre. The infested area and buffer zone, totalling 44,550 acres, was sprayed at a cost of $53,542 or $1.15 per acre.

INTRODUCTION

Aerial and ground surveys in 1961 showed that the budworm infestation present in Yakima and Klickitat Counties, Washington was increasing and could be expected to cause considerable tree killing in 1962.[1/] After an on-the-ground inspection of the infested area, the Northwest Forest Pest Action Council recommended the area be sprayed with DDT in 1962 to control budworm populations and prevent tree mortality.

The project was administered by the Washington State Department of Natural Resources with cooperation from private and federal land managers. Technical advice on the project was provided by the U. S. Forest Service.

Funds for the federal share of the project costs were made available under Public Law 110, the Forest Pest Control Act. The State of Washington advanced the private owners' share and was reimbursed later by individual owners.

Completion of this project brings the area sprayed for control of the spruce budworm in Oregon and Washington since 1949 to 4.7 million acres (table 1).

1/ Buffam, Paul E. Evaluation of 1962-63 spruce budworm populations in Oregon and Washington. U. S. Forest Serv., Pac. N. W. Region, 4 pp. Oct. 24, 1961.

Table 1.--Acreage treated, cost, and budworm kill obtained by aerial spraying in Oregon and Washington, 1949-62

Year	Area treated	Cost		Living budworm larvae in sample		Budworm mortality	
		Total	Per acre	Before spraying	After spraying	Range	Average
	Acres	- - Dollars - -		- - Number - -		- - Percent - -	
1949	266,000	320,000	1.20	8,350	200	88.9-100	97.6
1950	934,000	990,000	1.06	55,075	458	90.4-100	99.2
1951	927,000	983,000	1.06	22,424	308	74.0-100	98.6
1952	655,000	681,000	1.04	85,648	1,535	81.8-100	98.2
1953	369,000	350,000	.95	32,260	291	88.5-100	99.1
1954	68,000	63,000	.93	19,754	196	96.3-100	99.0
1955	621,000	658,000	1.06	84,244	2,606	79.0-100	96.9
1958	818,000	573,000	.69	33,594	1,275	70.1-100	96.2
1962	44,550	53,500	1.15	6,431	121	97.4-100	99.1
All years	4,702,550	4,671,500	.99	347,780	6,990	70.1-100	98.2

COOPERATION

The 1962 spruce budworm control project was a cooperative venture administered by Washington State Department of Natural Resources. Technical direction was provided by the U. S. Forest Service. Cooperation of the following individuals and organizations made the project run smoothly:

Boise-Cascade Corporation	J. F. Logan
Mt. Adams Search and Rescue Association	R. R. Sellers
Northwest Forest Pest Action Council	E. L. Kolbe, Chairman
U. S. Agricultural Research Service	K. C. Walker
U. S. Bureau of Indian Affairs	E. R. Wilcox
U. S. Public Health Service	J. H. Wilson
Washington State Pollution Control Commission	C. R. Ogden, R. E. Pine, and T. O. Clementson

PROJECT PLANNING

Planning an aerial spray project, whether large or small, is a major undertaking. Planning for the 1962 project began in the winter of 1961. The area to be sprayed was studied intensively to evaluate the many problems likely to be encountered. Analysis of many biological and administrative problems formed the basis for subsequent action during the project.

SAFETY

A safety plan was written in May 1962. Hazards likely to be encountered and steps to be taken in case of accident were recognized. Air search and rescue procedures to be used were described.

Safety was stressed throughout all project work. The contract included many provisions to safeguard all phases of the control operation. These provisions were developed from experience gained on large-scale control projects in Oregon and Washington from 1949 to 1958. All personnel were instructed in safe work procedures informally and at a formal safety meeting prior to the start of the project. No accidents marred the success of the 1962 project.

PLAN OF OPERATION

A plan was prepared early in the spring of 1962 outlining in detail organization of the project and responsibilities of cooperators.[2/] Procedures established were followed throughout the project. The following points were covered in the plan:

1. Cooperation among various participating agencies.
2. Financing the project.
3. Organization, assignment of individual responsibilities, and job descriptions.
4. Basic training plan.

2/ Anonymous. Plan of operation Simcoe Butte infestation control district number 3, spruce budworm control project in 1962 Yakima and Klickitat Counties. Wash. State Dept. Nat. Res., 13 pp. 1962.

TECHNICAL DIRECTION PLAN

The plan for the technical direction of the 1962 spruce budworm control project gave detailed procedures for the entomological phase of the project.[3/] The following points were covered in the plan:

1. Organization.
2. Responsibilities and duties of technical personnel.
3. Collection and processing budworm larvae.
4. Releasing spray blocks.
5. Sampling larval mortality.
6. Assessment of spray deposit.
7. General notes for biologists.

ORGANIZATION AND RESPONSIBILITIES

The infested area was located in Yakima and Klickitat Counties in Washington (figure 1). Since the majority of the area to be treated was on private forest lands, the Department of Natural Resources assumed responsibility for project organization and administration. The Forest Service was responsible for the technical phases--the training of biologists and insect checkers, technical inspection, and biological evaluation of results.

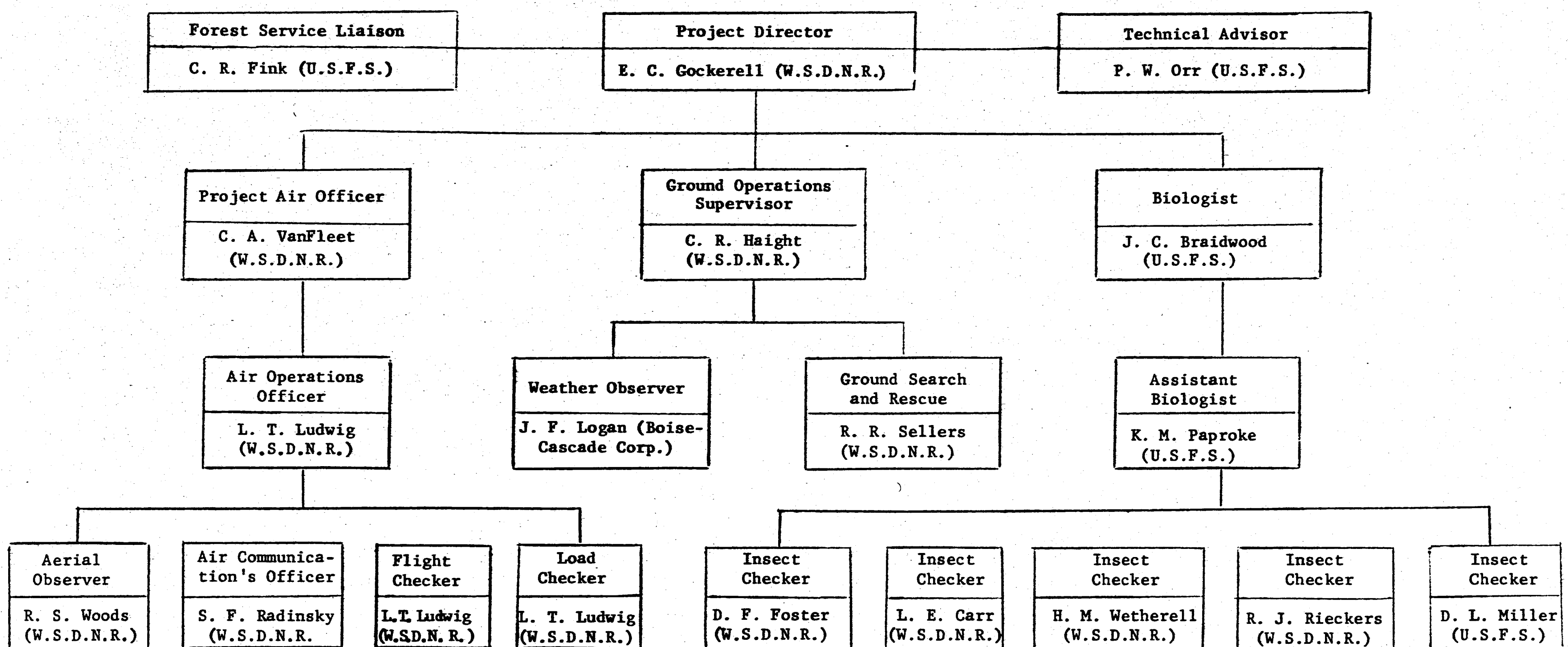
The State of Washington paid all costs on State, County, and Municipal lands, and 50 percent of the costs on private lands. Owners paid 25 percent of the costs on their lands. The Federal Government paid all costs on Bureau of Indian Affairs lands and 25 percent of the costs on private lands. Total costs on the project were as follows:

Private share	$ 10,348
State, County, and Municipal share.	25,101
Federal share	18,093
	$ 53,542

The project was administered as one unit because of its relatively small size. Organization structure and functional responsibilities are shown on the following chart:

3/ Orr, P. W. Plan for the technical direction of the 1962 spruce budworm control project in Washington. U. S. Forest Serv., Pac. N. W. Region, 20 pp. May 1962.

TECHNICAL ORGANIZATION FOR THE 1962 SPRUCE BUDWORM CONTROL PROJECT IN WASHINGTON



CONTRACTS

Contractual matters were supervised by the Department of Natural Resources. Aerial spraying, transportation of insecticide, and storage of insecticide were combined in one contract. This procedure differed from previous spray projects, but was done because of the relatively small size of the control job. The observation plane contract was separate. The contract for insecticide, transportation, storage and spraying was awarded on April 12 to Richardson Aviation, Yakima, Washington, for $0.84 per acre.

AERIAL SPRAY APPLICATION

The Yakima Municipal Airport was used as the base of operations despite the 50-mile ferry distance to the spray area. Using the existing airport facilities at Yakima Municipal Airport was more efficient than setting up administrative, fuel, and maintenance facilities at an unimproved airport closer to the spray area.

The contractor furnished three spray planes--two TBM Avengers and one FM Wildcat. The TBM's carried approximately 800 gallons of insecticide and the FM Wildcat carried 450 gallons. Qualified A&E mechanics were on call at the Yakima, Washington Airport.

OBSERVATION PLANE

A contract was let for one observation plane and pilot. Specifications required a 4-place, high-wing plane with at least a 200 horsepower engine capable of at least 150 miles per hour in level flight. The contract for this plane and qualified pilot was awarded to Richardson Aviation, Yakima, Washington, for $28.50 per hour. It was necessary to have an observation plane on the spray project to monitor the work of the spray pilots. The number of observation planes needed on a project will depend upon many factors, such as the topography, type of spray planes used, spray pilot ability, accessibility of the area for checking spray deposit, and others.

INSECTICIDE

The prime contractor obtained formulated insecticide from Stauffer Chemical Company of Portland, Oregon. The insecticide consisted of one pound of DDT dissolved in 1.25 quarts of auxiliary hydrocarbon solvent, with sufficient number 2 fuel oil added to make one gallon. Each batch of formulated insecticide was sampled at the supplier's plant before acceptance. These samples were tested by Dr. K. C. Walker at the Agricultural Research Service Laboratory, Yakima, Washington. All batches met, or exceeded, contract specifications for insecticide content, solvent properties, and other features.

AERIAL OPERATIONS

Air operations were centered at the Yakima, Washington Municipal Airport. A&E shops were located on the field and quarters were available nearby for project personnel. The Mt. Adams Search and Rescue group, based at the Goldendale headquarters, were on alert during all flying. The Goldendale Airport was used occasionally as a temporary base by the observation plane crew.

PROJECT AIR OFFICER

C. A. VanFleet, Department of Natural Resources pilot, was assigned as staff assistant to the project director. He gave advice and assistance to the project director in aerial matters and acted as liaison officer with the Civil Aeronautics Administration. His chief responsibilities were to train the observer, check pilot qualifications, inspect spray planes, and check spray equipment. He worked with the observer and biologist in monitoring spray operations and reviewing the work with the pilots. A qualified pilot as project air officer is essential for the success of a spray project especially in working out details of plane specifications, airfield layout, load limits, and other technical aerial problems.

AIRCRAFT INSPECTION AND CALIBRATION

Each bidder's aircraft were given a preliminary inspection by the project air officer before the contract was awarded. Final inspection to check on contract specifications was made by the air officer after the contract was awarded and before spraying began. Spray nozzles were calibrated by standard methods at the Yakima, Washington Airport. The aircraft safety requirements and airworthiness were checked by CAA personnel.

PILOT INDOCTRINATION

Prior to spraying, the pilots met in Yakima to discuss airfield operations, spray requirements, and other phases of the aerial work. Safe work methods were emphasized. Each pilot was shown the area boundary and individual spray block boundaries on aerial mosaic photos and from the air. As it turned out, more time should have been spent with the spray pilots in orienting them on boundaries. This requirement will vary from year-to-year, depending upon the pilot's ability and experience on spray operations.

AERIAL OBSERVATION

The observer, R. S. Woods, Department of Natural Resources, Glenwood, Washington, was given intensive training in judging height of flight, spray patterns, flight patterns, and in weather observation.

He was responsible for knowing precise spray block boundaries assigned for the day's spraying and for determining if the spray was settling down into the crown canopy or whether drift or heat inversions were preventing it from settling.

Each morning the observation plane was over the assigned spray block before the spray planes left the airstrip. This allowed time to observe weather conditions and make last minute changes in plans.

Continuous observation of the spray plane runs by a qualified observer was a valuable operational control. Small misses were picked up quickly. After spraying ceased for the day, the observer and spray plane pilots marked the progress on project maps in the Yakima office.

FLIGHT PATTERNS AND BLOCK LAYOUT

After thorough aerial and ground reconnaissance of the area, the project director, technical advisor, and biologist delineated the spray blocks. In general, these blocks were laid out on contours allowing for long spray plane runs (figure 1). As the work progressed, subdivision of many of the spray blocks was necessary to meet different larval development patterns of the spruce budworm. This prevented long spray runs in some instances.

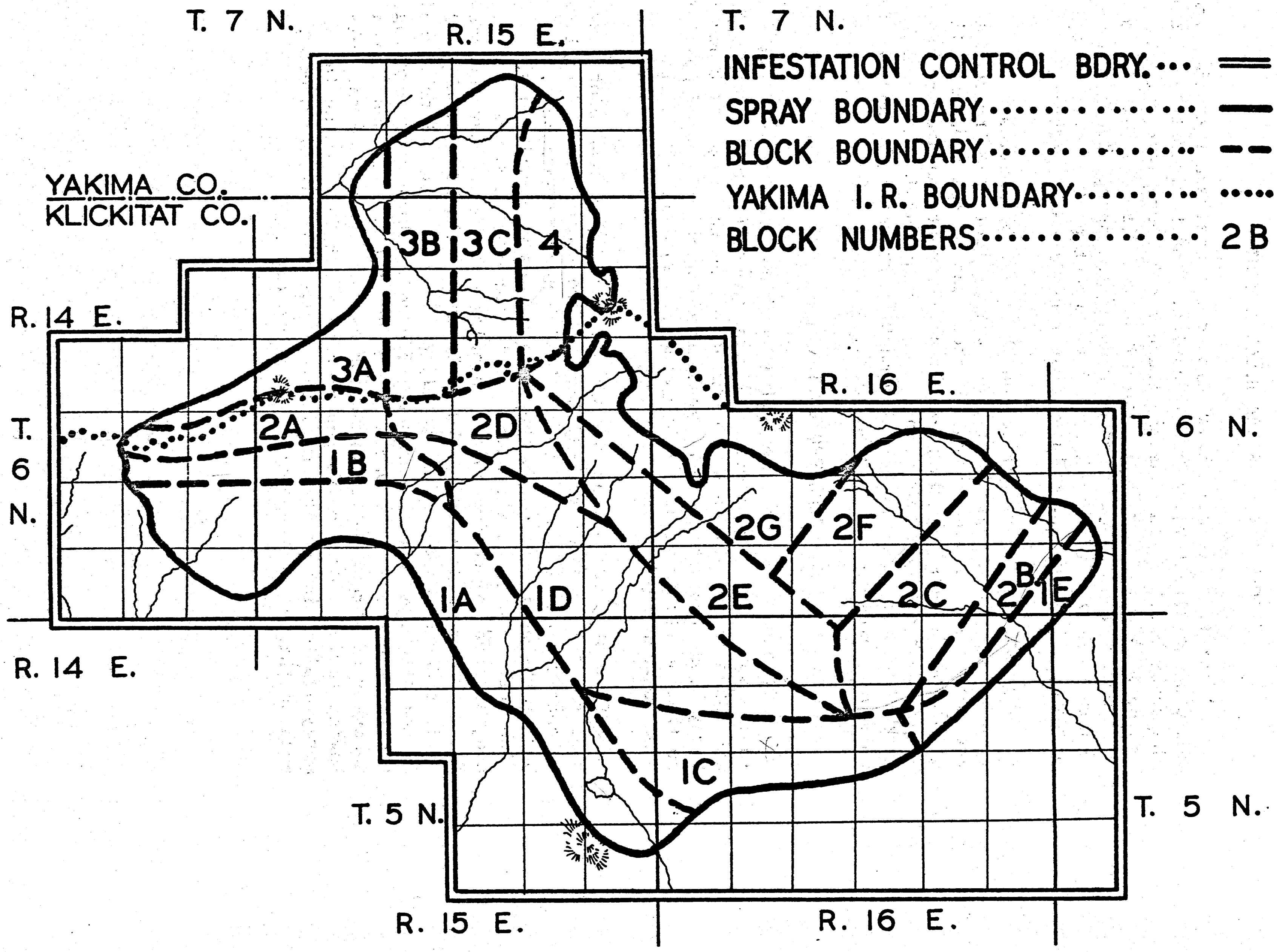
Spray pilots were briefed on the block boundaries and locations by the project director, air officer, and the contractor. Each pilot was provided with a contour map of the area and all pilots had access to a large-scale aerial photo mosaic of the area. Some of the pilot errors in spraying outside the area could have been eliminated by actually marking the block boundaries with balloons, smoke pots, or other methods.

FISH PROTECTION

Although there were no important fish-producing streams in the spray area, some were used for sport fishing. Every effort was taken to prevent water contamination in the larger streams. Spray block boundaries were established on ridge tops if possible so that no stream would receive a double dose of insecticide from adjacent spray blocks.

Some observations of the spray effects on stream biota were made by Washington State Pollution Control Commission biologists in cooperation with U. S. Public Health Service personnel. During the period in which the observations were made no dead fish were found, but the number of bottom organisms was reduced and, at some collection points, populations were almost depleted. Three streams were studied--Lower Bowman Creek, Mill Creek, and Devil's Canyon Creek. Immediately after spray operations ceased, bottom organism populations were affected. Throughout spraying, the trout and other fish present in the streams were unaffected. Recovery of stream bottom organisms was about complete the following spring. Continuing research on the effects of aerial spray application on stream biota and water quality is needed, both on this and other aerial spray projects.

FIGURE 1


T. 7 N.
R. 15 E.
T. 7 N.
INFESTATION CONTROL BDRY.
SPRAY BOUNDARY
BLOCK BOUNDARY
YAKIMA I. R. BOUNDARY
BLOCK NUMBERS 2B
YAKIMA CO.
KLICKITAT CO.
R. 14 E.
3B
3C
4
3A
2A
2D
1B
T. 6 N.
R. 16 E.
T. 6 N.
2G
2F
1A
1D
2E
2C
2B
1E
1C
R. 14 E.
T. 5 N.
T. 5 N.
R. 15 E.
R. 16 E.

AIRFIELD OPERATIONS

Operations at the Yakima Municipal Airport ran smoothly during the project. The operations staff consisted of a communications officer and a combination flight checker-load checker. One man handled loading and metering of insecticide into the planes.

At the outset, some difficulties developed in the insecticide storage facilities. Numerous leaks and dirt in the system were encountered. A complete flushing of the system and careful re-installation of pipes and hoses eliminated the problem.

The Yakima, Washington, Fire Marshal considered that above-ground storage of insecticide posed a fire hazard. A stand-by fire truck and installation of adequate fire extinguishers met the Fire Marshal's objections.

COMMUNICATIONS

Communication needs were carefully planned well in advance of spraying. With the exception of plane-to-plane contact, communications were adequate. For ground communications, Grayback Lookout served as the relay station for traffic between the airfield in Yakima and biological headquarters at Goldendale. This relay station was in operation from dawn to dusk for emergency calls. After each day's spraying, public telephone services were used to free the radio for fire calls.

AERIAL SPRAYING

Spraying began on June 25 at the lowest elevations. No areas were released for spraying on June 28 or 29 because of slow budworm development. Spraying was resumed again on June 30 but winds prevented spraying on July 1. On July 2 spraying commenced once more and continued through July 11, with off-days on July 5 and 7 to await larval development. A summary of spray operations is as follows:

Date	Acres sprayed	Date	Acres sprayed
June 25	4,286	July 4	4,102
June 26	5,856	July 6	4,966
June 27	2,750	July 8	2,801
June 30	8,171	July 9	2,939
July 2	2,825	July 10	2,130
July 3	1,401	July 11	2,318
		Total sprayed	44,545

Weather during the spraying operations was often windy and cool both day and night. Occasionally an inversion layer was present at about the 3,500-foot elevation on Simcoe Butte. These weather conditions retarded budworm larval development about a week.

BIOLOGICAL PHASES

All entomological phases of the project, from delineating the area to be sprayed to checking results of the spraying, were the responsibility of the technical director. A biologist, assistant biologist, and five insect checkers performed the field work as shown in the organization chart on page 5.

Headquarters for all biological work was located at the Department of Natural Resources subdistrict office at Goldendale. This location provided easy access to the spray area.

SURVIVAL OF OVERWINTERING BUDWORM LARVAE

In April 1962, limb and bole samples of grand fir and Douglas-fir trees were taken at seven representative locations within the project area to determine if winter mortality had reduced larval populations sufficiently to preclude spraying. The weighted average emergence per 100 square inches of bark area was 17.8 larvae.[4/] Past experience has shown that this number of emerging larvae can cause serious defoliation. Thus, spraying was considered necessary to protect timber values.

LARVAL DEVELOPMENT

Larval development was determined by examination of larvae collected each day. Collection procedures were the same as those used on previous control projects in Oregon and Washington. Larvae were collected from 21 permanent sampling points and from a number of temporary collecting points. Daily collections began on June 6, about the time budworm larvae started to enter the swelling buds at low elevations (2,500-3,000 feet). On this date, larvae at medium elevations (3,000-3,500 feet) were still in the needle-mining stage. At high elevations (3,500-4,500 feet), very little needle-mining had yet occurred and no bud mining was seen.

4/ Braidwood, John C. Report on forced emergence of overwintering spruce budworm larvae for the proposed 1962 State of Washington control project. U.S. Forest Serv., Pac. N.W. Region, 7 pp. May 1962.

Larvae development on Douglas-fir consistently lagged three to four days behind that on grand fir (table 2). This meant that spraying had to be delayed beyond optimum spray time on grand fir in order to let larval development on Douglas-fir reach the suitable stage for control. However, no pupation occurred on grand fir prior to spraying. Differences between larval development in the two host species is believed to result from variation in bud development. Bud opening in grand fir preceded that on Douglas-fir by as much as 10 days (figure 2).

The first-spray block release was almost a week premature. Unusually low temperatures occurred throughout June and well into July. As a result, larval development was delayed considerably. The original four spray blocks were subdivided to allow apraying at the most opportune time. Larvae development rates on Douglas-fir are shown in figure 3 and those on grand fir are shown in figure 4.

FIGURE 2

BUD DEVELOPMENT ON WHITE FIR AND DOUGLAS-FIR SIMCOE BUTTE, WASHINGTON 1962

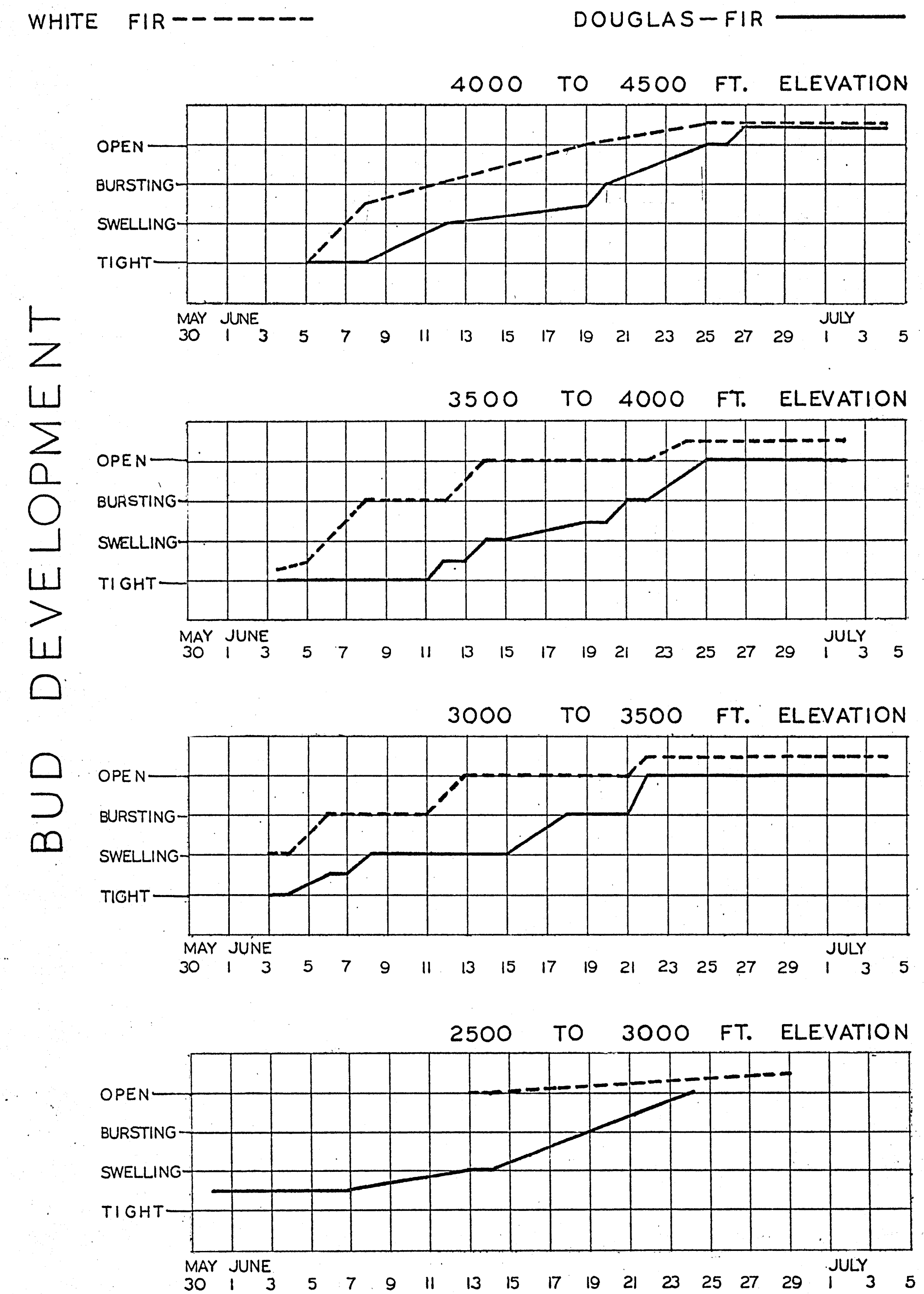


FIGURE 3

SPRUCE BUDWORM LARVAL DEVELOPMENT ON DOUGLAS-FIR

GOLDENDALE, WASH. 3,000-3,500 FT. ELEVATION

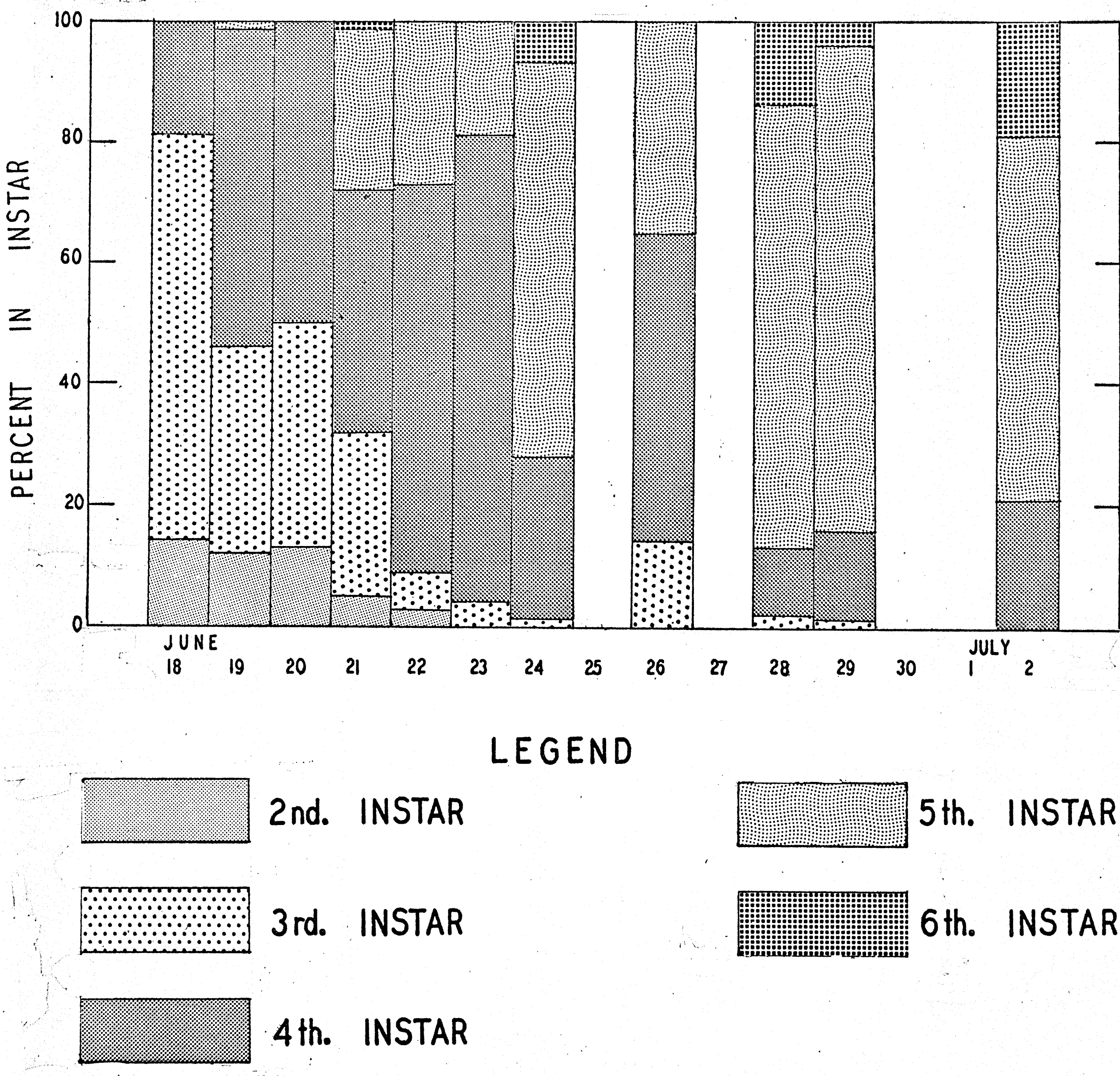


FIGURE 4

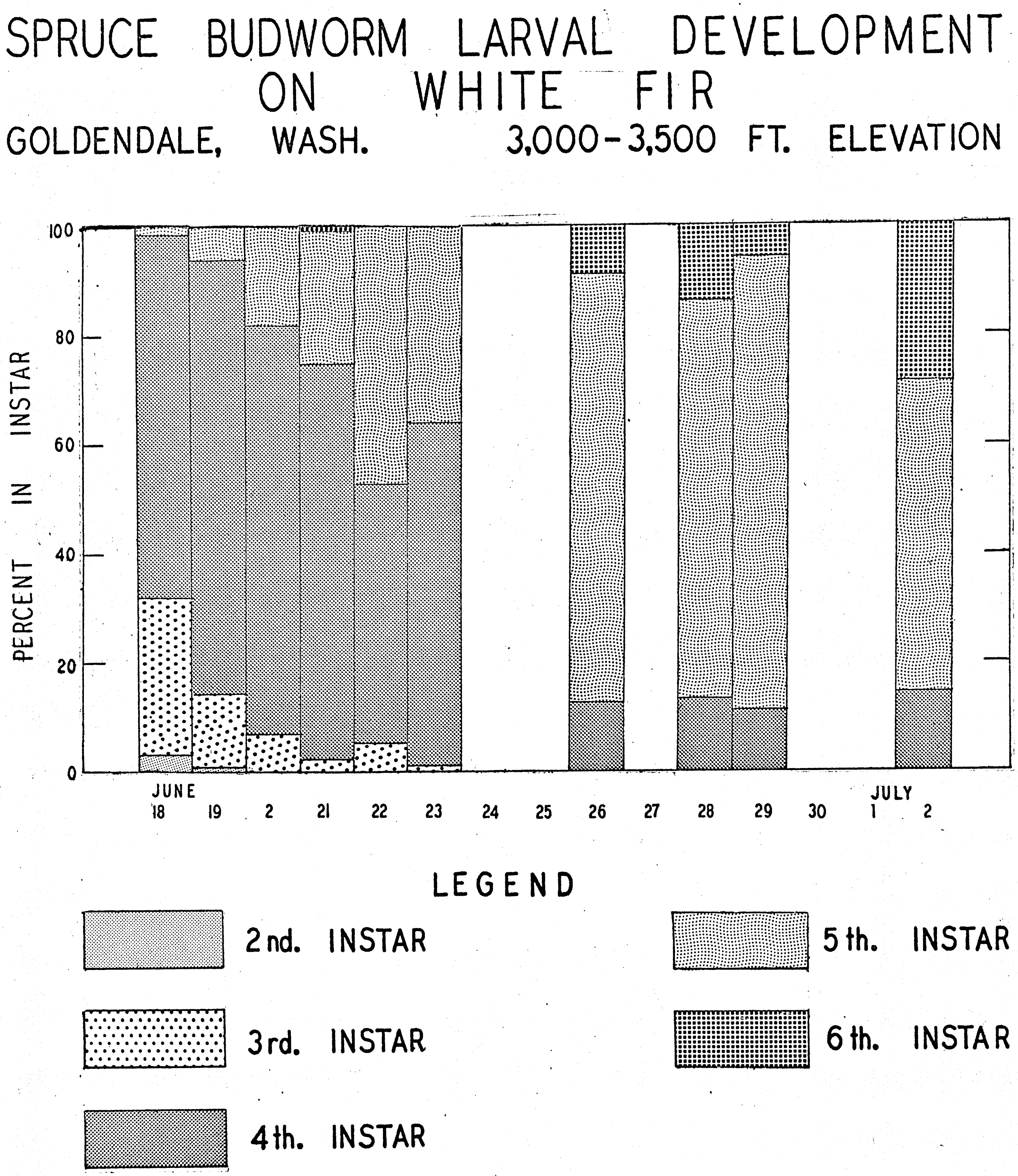

SPRUCE BUDWORM LARVAL DEVELOPMENT
ON WHITE FIR
GOLDENDALE, WASH. 3,000-3,500 FT. ELEVATION
PERCENT IN INSTAR
100
80
60
40
20
0
JUNE
18
19
2
21
22
23
24
25
26
27
28
29
30
JULY
1
2
LEGEND
2nd. INSTAR
3rd. INSTAR
4th. INSTAR
5th. INSTAR
6th. INSTAR

Table 2.--Spruce budworm larval development on grand fir and Douglas-fir at various elevations on the Simcoe Butte control project - 1962

Date	Elevation	Grand fir					Douglas-fir				
		Larval instar					Larval instar				
		II	III	IV	V	VI	II	III	IV	V	VI
	Feet	Percent									
6/18	2,500-3,000	0	0	25	75	0	5	10	64	21	0
6/19		0	13	15	72	0	2	23	54	21	0
6/20		0	0	14	86	0	1	24	41	34	0
6/21		0	0	14	66	20	0	9	16	75	0
6/22		1/	1/	1/	1/	1/	0	2	25	69	4
6/23		1/	1/	1/	1/	1/	0	0	33	63	4
6/18	3,000-3,500	3	29	67	1	0	14	67	19	0	0
6/19		1	13	80	6	0	12	34	53	1	0
6/20		0	7	75	18	0	13	37	50	0	0
6/21		0	2	73	24	1	5	27	40	27	1
6/22		0	5	48	47	0	3	6	64	27	0
6/23		0	1	63	36	0	0	4	77	19	0
6/24		1/	1/	1/	1/	1/	0	1	27	65	7
6/26		0	0	12	79	9	0	14	51	35	0
6/28		0	0	13	73	14	0	2	11	73	14
6/29		0	0	11	83	6	0	1	15	80	4
7/7		0	0	12	59	29	0	0	21	60	19

1/ No collections made.

MORTALITY SAMPLING

Budworm mortality due to spraying was determined by comparing pre- and post-spray larval populations on 15-inch branch samples of grand fir and Douglas-fir. One or two days before spraying a mortality line was established in each block to be sprayed. Five sampling plots, five chains apart, were located along this line. At each plot five trees were tagged and two 15-inch branches were clipped from the mid-crown area of each tree. The larvae from each branch were counted and preserved in alcohol for determination of larval instar in the laboratory.

A total of 11 mortality lines were established on the project area. Of these lines, four were contaminated by spray drift from adjacent blocks. One line showed only 38 percent mortality on the three-day check and was resprayed one day later. Hence, these five lines were eliminated from the comparison of three and ten-day mortality.

Post-spray mortality sampling procedures differed from pre-spray sampling in that four 15-inch branches were clipped from each tree and examined for surviving budworm. Larval mortality was then computed by the following formula:

$$\text{Percent mortality} = \frac{\text{Pre-spray count x 2 - Post-spray count}}{\text{Pre-spray count x 2}} \text{ x 100}$$

TEN-DAY MORTALITY CHECK

Mortality recorded 10 days after spraying averaged 99.1 percent, ranging from 97.4 percent to 100 percent in individual blocks. This mortality level is considered excellent by standards established and used on previous control projects.[5/] The final mortality was greater than that shown by sampling because some of the surviving larvae later died from parasitism or other causes. No abnormal budworm populations were found on the area the following summer.

The 10-day mortality check has been the standard used to rate effectiveness of budworm control for several years. This 10-day wait has been necessary to allow as many larvae as possible to come in contact with the DDT.

5/ Howard, Benton and Whiteside, J. M., 1958 spruce budworm control project, Oregon. U.S. Forest Serv., Pac. N.W. Region, 43 pp., illus. 1958.

Biologists have felt the need to assess the effectiveness of the control operation two or three days after spraying. This would permit respraying before the budworm pupated.

THREE-DAY MORTALITY CHECK

Three days after spraying, larval mortality was considerably lower than at ten days after spraying as indicated below:

Sample line	Average larval mortality: Three days after spraying	Average larval mortality: Ten days after spraying
	- - - - - Percent - - - - -	
1	87.9	99.8
3	88.8	100.0
5	90.1	99.7
6	92.7	99.8
7	66.8	97.4
9	86.4	99.5

The correlation between spruce budworm larval mortality three days after spraying and ten days after spraying is highly significant at the one percent level for both individual plots and mortality line averages. Since 90 percent mortality is the lowest point at which control is conisdered effective, the 3-day sample cannot be used as the final measure of control. However, it may well be a useful estimate of the final mortality that is likely to occur. Further tests of this method of predicting final larval mortality should be made on future projects.

SPRAY DEPOSIT ASSESSMENT

Oil-sensitive dye cards were used to record spray deposit reaching the forest floor. The 4x5-inch cards were stapled to 10x12-inch heavy cardboard backing sheets and placed at 0.1 mile intervals along roads in the spray area. The cards were usually set out one day before spraying and picked up on the day spraying was performed. A total of 488 cards was set out on the 44,550-acre spray area, or an average of one card per 92 acres.

Location and Placement

The project area had a complete network of roads, which made ideal locations for placement of spray cards on roads running perpendicular to the line of flight. Time required in laying out and picking up cards was minimized by using a two-man crew. One man drove the car and recorded the card number and location on a map. The other man placed and retrieved the cards.

As many cards as time and manpower would permit were set out. This seemed to be the best way to check that each block was sprayed completely, thus increasing the chances for maximum overall budworm mortality. Placing cards at 0.1 mile intervals provided an intense check on block coverage and gave some check on coverage between swaths. In total, 43 card lines were established on the 16 spray blocks or 2.7 card lines per block.

Effectiveness

Spray deposit, as determined by examination of individual cards, ranged from 0.0 gallons per acre to 4.4 gallons per acre when compared with established standards.[6/7/] The average spray deposit is shown for each spray block in the following tabulation.

On other spray projects there has been considerable speculation about the relationship between apparent spray deposit on oil-sensitive cards and eventual budworm mortality. Some workers feel that there is no meaningful correlation because the crown canopy intercepts much of the deposit. Hence, light deposit on the cards may mean heavy larval mortality and vice versa. This apparently occurred on this project as indicated in the following tabulation.

6/ Davis, J. M. and Elliott, K. R. A rapid method for estimating aerial spray deposits. Jour. Econ. Ent. 46(4): 696-698. Aug. 1953.

7/ Davis, J. M. Standards for estimating airplane spray deposits in oil-sensitive cards. U. S. Dept. Agric. 1953.

Block number	Area	Estimated spray deposit per acre	Resulting larval mortality
	Acres	Gallons	Percent
1-A	8,000	0.333	100.0
1-B	1,900	0.298	1/
1-C	3,200	0.212	99.2
1-D	5,400	0.446	99.8
1-E	1,200	0.246	1/
2-A	1,340	0.345	1/
2-B	1,649	0.449	1/
2-C	2,500	0.292	98.8
2-D	1,839	0.674	97.4
2-E	3,250	1.279	99.8
2-F	2,939	0.461	1/
2-G	2,103	0.630	1/
3-A	1,800	0.511	1/
3-B	2,500	0.456	99.5
3-C	2,530	0.391	98.3
4	2,350	0.753	1/
	44,500	Wtd. mean 0.501	99.1

1/ No mortality line established.

In any case, the use of the oil-sensitive dye spray deposit cards will give a rough estimate of the insecticide reaching the forest floor. It is quite likely that heavier deposits occurred in the tree tops.

Spray cards proved very effective in checking pilot accuracy and as proof that misses had occurred. The intense placement of cards enabled detection of relatively small misses which were reflown as soon as possible. Considerable added expense to the contractor was avoided since small portions of a block missed in the original flight could be reflown without requiring respraying of the entire block.

OTHER METHODS OF ASSESSMENT

Observations of spray droplets on understory plant foliage as an indicator of spray coverage were made. California hazel, willow, manzanita, strawberry, wild rose, and vetch were good indicators of spray deposit; others, such as balsam root, were only poor indicators. In many places, however, the scarcity of these plants made detection of spray droplets by this method unreliable. In some instances spray deposit could be seen on down logs, rocks, and puddles. Little reliability could be placed on these objects as indicators of spray distribution.

Oil odor in sprayed areas is a good indicator immediately after spraying but relies on the olefactory senses of the individual checker. Furthermore, the odor of the oil may drift for considerable distances.

Oil-sensitive cards are the most consistent non-quantitative method of evaluating spray deposit. All other methods tested depend upon the judgment of the individual and offer no means of obtaining quantitative data.

RECOMMENDATIONS

Based on experience gained on the 1962 project, the following items should be considered on future projects:

1. The project director and biologist should maintain daily personal contact for effective communications.

2. Use of oil-sensitive dye cards should be continued to detect and assess spray coverage. The cards should be distributed and retrieved by someone not connected with the biological work on the project.

3. Final larval mortality should be made 10 days after spraying. Results of the 3-day larval mortality tests were inconclusive and cannot be recommended for operational use without further testing. Studies should be continued to determine if control effectiveness can be assessed two or three days after spraying.

4. Maintain a record of day and night temperatures in the spray area prior to spraying to determine rate of larval development.

5. Mark spray boundaries with balloons, smoke pots, or other devices. Unmarked boundaries could result in costly mistakes.

6. Larval development should be determined by examining fewer larvae from more collection points. At the points, larvae should be collected from several different trees and from different aspects on the same tree.

7. Larval collections to determine development should be made only twice a week until a substantial part of the population reaches the fourth instar.

8. Use of fluorescent dye tracers should be investigated for use on future projects.

9. Insecticide and solvent specifications should be reviewed and modified as needed on each project.

10. Planes should be loaded with a high volume recording metered pump.

11. Insecticide storage and handling facilities must be flushed and thoroughly inspected prior to use.